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L1: Entry 7 of 8 File: DWPI Sep 24, 1999

DERWENT-ACC-NO: 1999-596763
DERWENT-WEEK: 200427

TITLE: Processing of transparent thin film formed on semiconductor substrate - involves detecting thickness reduction in transparent thin film using monitor during etching based on which etching conditions are altered

Hiroshi

PRIORITY-DATA: 1998JP-0062524 (March 13, 1998)

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PATENT-FAMILY:

PUB-NO	PUB-DATE	LANGUAGE	PAGES	MAIN-IPC
JP 11260799 A	September 24, 1999		008	H01L021/3065

INT-CL (IPC): C23 F 4/00; H01 L 21/3065

ABSTRACTED-PUB-NO: JP 11260799A
BASIC-ABSTRACT:

NOVELTY - The transparent thin film is etched optically using plasma with pressure of 0.1 Pa or less. The thickness reduction in the thin film to a preset value is detected using a real time film thickness monitor based on which etching conditions are altered.

USE - Used for processing transparent thin film formed on semiconductor substrate for gate electrode of semiconductor device e.g. MOS transistor.

ADVANTAGE - Prevents microtrench and charge-up damage of oxide film generated near etching end point of polysilicon. Reduces shape difference and coarseness appearance difference of wafer.

DESCRIPTION OF DRAWING(S) - The figure shows etching apparatus.

Previous Doc Next Doc Go to Doc#

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 11-260799
(43)Date of publication of application : 24.09.1999

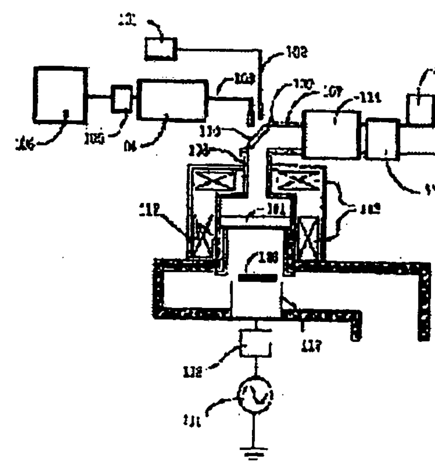
(51)Int.Cl. H01L 21/3065
// C23F 4/00

(21)Application number : 10-062524
(22)Date of filing : 13.03.1998
(71)Applicant : HITACHI LTD
(72)Inventor : MIYAZAKI HIROSHI

(54) FINE WORKING METHOD OF THIN FILM

(57)Abstract:

PROBLEM TO BE SOLVED: To realize low gas, high bias voltage, etc., and reduce in-plane form difference and the like, by monitoring the residual film thickness of polysilicon, and performing changeover to a high selective etching condition just before a gate oxide film is exposed, when a polysilicon film is etched as far as the midway of film formation with a specified low gas pressure.



SOLUTION: A quartz window 110 is installed in a conversion waveguide 109 for introducing microwave into a circular waveguide 108. An optical fiber 102 for white light irradiation and an optical fiber 103 for taking in a plasma light reflected by a wafer surface are installed in the window 110. The light taken in the optical fiber 102 is spectrally analyzed by a spectroscope 104, and converted to an electric signal by using a photoelectric multiplier tube 105. A waveform analyzer 106 calculates an etching film thickness. The polysilicon film is etched as far as the midway of the film formation, with a low gas pressure of a most 0.1 Pa. The residual film thickness of polysilicon is monitored by using a light interference type real time film thickness monitor. Just before a gate oxide film is exposed, changeover to a high selective etching condition is performed.

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H01L 21/3065		H01L 21/302		E
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審査請求　未請求　請求項の数9　OL　（全 8 頁）

(21)出願番号　特願平10－62524

(22)出願日　平成10年(1998) 3月13日

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(54)【発明の名称】　薄膜の微細加工方法

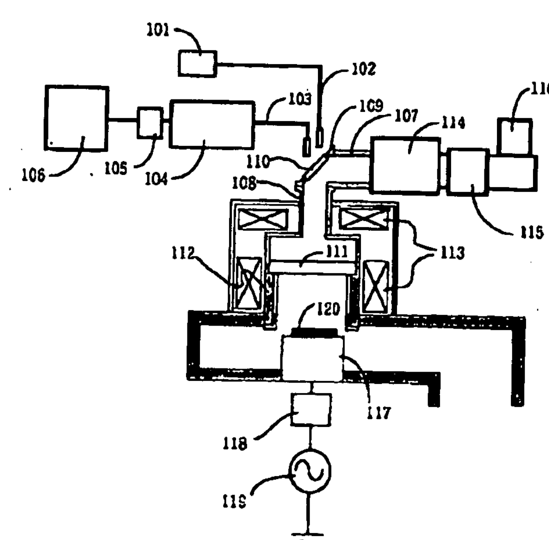
(57)【要約】

【課題】半導体装置のゲート電極加工においてウエハの大口径化やパターンの疎密によって生じるエッチング均一性の低下を防止する。

【解決手段】0.1Pa以下の低ガス圧力条件でゲート電極のエッチングを行う。ポリシリコンの終点時に起こる酸化膜の損傷を防止するため、光干渉式リアルタイム膜厚モニタでポリシリコン残膜を検知し、終点直前に高選択エッチング条件に切り換える。

【効果】直径300mmの大口径ウエハでも高精度で加工できる。

図1



【特許請求の範囲】

【請求項1】光学的に透明な薄膜を有する試料を圧力0.1Pa以下のプラズマを用いてエッチングする工程において、

前記試料の透明薄膜が所定膜厚まで減少したことをリアルタイム膜厚モニタで検知し、当該検知に応答してエッチング条件を変更することを特徴とする薄膜の微細加工方法。

【請求項2】リアルタイム膜厚モニタによる所定膜厚検知後に、ガス圧力を1Pa以上に高めることを特徴とする請求項1記載の薄膜の微細加工方法。

【請求項3】リアルタイム膜厚モニタによる所定膜厚検知後に、反応ガスを臭素と酸素の混合ガスに切り換えることを特徴とする請求項1記載の薄膜の微細加工方法。

【請求項4】リアルタイム膜厚モニタによる所定膜厚検知後に、基板に印加するrf電力を30W以下に下げることを特徴とする請求項1記載の薄膜の微細加工方法。

【請求項5】リアルタイム膜厚モニタによる所定膜厚検知後に、基板に印加するrf電力を、デューティ比20%以下でON-OFF変調することを特徴とする請求項1記載の薄膜の微細加工方法。

【請求項6】リアルタイム膜厚モニタによる所定膜厚検知後のエッチング条件変更が、請求項2から5までの要件を少なくとも一つ以上含み、かつこれらを複数組み合わせたことを特徴とする請求項1記載の薄膜の微細加工方法。

【請求項7】リアルタイム膜厚モニタは、試料の白色光を照射する第1の光ファイバーと、当該試料からの反射光を取り込む第2の光ファイバーと、当該第2の光ファイバーで取り込んだ反射光を分光する分光器と、当該分光した反射光を電気信号に変換する光電増倍管とを具備して成る請求項1記載の薄膜の微細加工方法。

【請求項8】リアルタイム膜厚モニタは、試料の白色光を照射する第1の光ファイバーと、当該試料からの反射光を取り込む第2の光ファイバーと、当該第2の光ファイバーで取り込んだ反射光をフィルタリングする光フィルターと、当該フィルタリングした反射光を電気信号に変換する光電増倍管とを具備して成る請求項1記載の薄膜の微細加工方法。

【請求項9】ポリシリコンのエッチング膜厚測定に用いる光の波長は、290-360nmであることを特徴とする薄膜の微細加工方法。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は半導体基板上に設けられた光透過性薄膜の微細加工方法に関する。

【0002】

【従来の技術】光干渉式膜厚モニタについては第19回ドライプロセスシンポジウムの235頁から242頁(Proceedings of Symposium on Dry Process, November 12-14, Tokyo (1997), p.235-242)に記載されている。

【0003】また、ウエハ面内のエッチング均一性を高めるためにフォーカスリングを用いる方法については例えば特願平6-033645に記載されている。

【0004】

【発明が解決しようとする課題】大規模集積回路(LSI)の高密度化・高速化の要請から，MOS(metal-oxide-semiconductor)トランジスタのゲート電極は将来的には線幅0.2μm以下まで縮小され，下地のゲート酸化膜は4nm以下まで薄膜化される。同時に、製造コスト削減のためシリコンウエハは200mmから300mmに大口径化される。したがって，ゲート電極のドライエッチングでは以下に述べる問題を解決する必要がある。

【0005】すなわち、MOSトランジスタでは動作特性を揃えるためゲート電極底辺の寸法(CD;critical dimension)を±0.02μm以下の精度で加工することが必須である。ところが，面内位置やパターン疎密度によって仕上がり寸法に差が生じる。これらは、それぞれ、面内形状差および疎密形状差と呼ばれ、微細加工の障害になっている。

【0006】ウエハ面内でガス濃度やプラズマ密度が不均一な場合、面内形状差が生じる。すなわち、反応生成物の濃度が高くなる中央部では側壁堆積物が増加してパターンが太る傾向にある。また、大口径ウエハでは大きな濃度分布が生じるため，面内形状差はより顕著になる。

【0007】一方，パターン自体の遮蔽効果によって生じる疎密形状差も大きな問題である。すなわち、パターン間隔が狭くなるとイオンやラジカル、反応生成物の入射量が低下する。そのため、エッチング速度は遅くなるが、パターンは太らない。逆に孤立パターンやオープンスペースに面したパターンでは、密パターンよりも反応生成物の入射量が多く側壁に堆積し、パターンが太る傾向にある。

【0008】前記した両形状差ともガス圧力の影響を強く受ける。すなわち、ガス圧力が高くなると、分子どうしの衝突散乱が増えて水平方向への分子移動が抑制され面内のガス濃度分布が大きくなること、及び衝突散乱が頻繁になって反応生成物の再入射量が増えるために疎部への側壁堆積量が非常に大きくなることが分かっている。

【0009】従来のエッチング技術では、プラズマ密度の面内分布を調整することでガス濃度分布の不均一を相殺していた。ただし、この方法では実用に適したエッチング条件の範囲が狭くなり、プロセス不安定性の原因になっていた。このため、ウエハをリング状の障壁(フォーカスリング)で囲み、その中にガスを淀ませることによって反応生成物の濃度を均一にする方法が用いられている。しかし，疎密形状差については有効な対策手段が殆どなく、現時点ではガス圧力を下げることが最も効果

的である。

【0010】ガス圧力を0.1Pa以下まで下げると形状差は低減できるが、半導体装置の量産ではこのような低圧力条件は好まれない。その理由は、エッチング速度が低下してウエハ処理能力が落ちること、ゲート酸化膜に対する選択比が低下すること、電子シェーディングによる形状異常やチャージアップダメージが発生すること等の弊害があるからである。

【0011】これらの問題も個別にはエッチング条件を選ぶことで解決できる。低圧でも、基板に印加するバイアス電圧を高くし、ガス流量を増やすせば、高速でポリシリコンがエッチングできる。しかし、従来のエッチング終点判定技術を用いる限り、終点付近で低圧、かつ高バイアスのエッチングは破綻する。すなわち、プラズマ発光や基板バイアス電圧の変化をモニタする方法は、いずれもフィードバック方式であるため、終点検出時にはゲート酸化膜のエッチングがかなり進行しているからである。この時点でエッチング条件を変更しても酸化膜の損傷は避けられないない。したがって、ゲート酸化膜が露出する直前に選択比の高いエッチング条件に変更することが必須である。

【0012】最近になって、光干渉式膜厚モニタ(第19回ドライプロセスシンポジウムの235頁から242頁に記載)が考案され、エッチング中のポリシリコンの膜厚測定が可能になった。ただし、エッチング制御への応用例は殆どない。

【0013】本発明の目的は、低ガス圧、かつ高バイアス電圧、高ガス流量エッチングを実現し、面内形状差や疎密形状差を低減することのできる薄膜の微細加工方法を得ることにある。

【0014】

【課題を解決するための手段】上記の目的を達成するため、本発明においては、ゲート電極加工工程において、0.1Pa以下の低ガス圧力でポリシリコン膜の途中までエッチングをする。このエッチング中にポリシリコンの残膜厚を光干渉式リアルタイム膜厚モニタで監視し、ゲート酸化膜が露出する直前(残り300nm以内)で高選択エッチング条件に切替える。

【0015】

【発明の実施の形態】図1に本発明の一実施例を示すエッチング装置の概要を示す。

【0016】マイクロ波を矩形導波管107から円形導波管108に導入するための変換導波管109に石英窓110を設け、この窓110に白色光を照射するための光ファイバー102、およびウエハ表面で反射したプラズマ光を取り込むための光ファイバー103を設置する。101は白色光光源であり、光ファイバー102に白色光を供給する。取り込んだ光は分光器104で分光し、光電増倍管105を用いて電気信号に変換し、波形解析装置106にてエッチング膜厚を算出する。この分光器104は光フィルターであっても良い。ポリシリコンのように光学的に透明な薄膜では、薄膜上面で反射された光と薄膜下面で反射された光が干渉するため、エッチングによる膜厚減少に対応して反射強度が周期的に変化する。したがって、薄膜の屈折率が既知の場合は位相変化量からエッチング膜厚が計算できる。この薄膜上に別種の透明なエッチングマスクが存在する場合でも、膜厚変化の測定が可能である。

【0017】なお、図1において、116はマイクロ波の供給源であるマグネトロン、115はアイソレータ、114はチューナである。112は反応容器であり、111は石英窓、113は反応容器112内に磁場を形成するソレノイドである。117はウエハ120を搭載する電極、119は電極117にバイアス電力を供給するｒｆ電源、118は電極117へ供給する電力を調整するマッチングボックスである。

【0018】図2に有機レジストを用いてMOSトランジスタのゲート加工を行った場合の光反射強度変化の一例を示す。これは分光器104で波長320nmの反射光を取り出し、その強度変化をモニタした結果である。これによれば、レジストの屈折率(n=1.5)に対しポリシリコンの屈折率(n=5.2)が約一桁小さいことに対応して、ポリシリコンからの反射光の方が有機レジストからの反射光よりも3.5倍ほど短い周期で変化している。

【0019】加工マスクとして窒化シリコン膜や酸化シリコン膜を用いても、同様の理由からリアルタイムで膜厚が測定できる。以下、この膜厚測定器を光干渉式リアルタイム膜厚モニタと称する。

【0020】目的とする高度なマルチステップ・エッチングを行うためには、低圧エッチングと光干渉式リアルタイム膜厚モニタを組み合わせることが必要である。低圧でエッチングを行えば、面内/疎密のエッチング速度差はなくなる。ウエハ面内でエッチングが均一に進行するので、光干渉式リアルタイム膜厚モニタによりエッチング膜厚が正確に測定できる。このため、タイミングよくエッチング条件を切り換えることが可能になり、低圧エッチングでもゲート酸化膜の損傷が防止できる。すなわち、低圧エッチングと組み合わせることで、光干渉式リアルタイム膜厚モニタの能力を十分引き出すことができる。

【0021】本発明によるエッチングの実施例について説明する。

【0022】(実施例1)図3にエッチング試料の断面構造を示す。これは、直径300mmのシリコンウエハ301上に3nmの酸化膜302、200nmのn^+ドープドポリシリコン膜303、200nmの窒化シリコン膜304がこの順序で積層されている。窒化シリコン膜304はレジストマスクによって加工されており、最小線幅は0.13μmである。

【0023】表1に4通りのマルチステップ・エッチング方法を示す。各々はポリシリコン膜303のエッチング時のガス圧力(0.1Pa, 0.4Pa)と終点検出方法(光干渉式リアルタイム膜厚モニタ、プラズマ発光モニタ)の組合せ

が異なっている。基板に印加するrf電力とガス流量を調節して処理時間が同じになるようにあらかじめ各々のエッチング条件を定めた。この前提の下で各方法の優劣を比較した。図4に各モニタ信号と膜厚の時間変化を示した。また、表2にウエハ中央部と周辺部における孤立パ＊ターンと密パターンのCDシフト量およびマイクロトレンチ(微細な孔)の発生有無を示した。

【0024】

【表1】

表1(a)

<table>
<tr><td rowspan="5">プラズマ発光モニタ
切換え</td><td rowspan="2">ステップ</td><td colspan="3">ガス流量(ml/min)</td><td rowspan="2">圧力
(Pa)</td><td rowspan="2">rf電力
(W)</td><td rowspan="2">マイクロ波
(W)</td><td rowspan="2">基板温度
(℃)</td></tr>
<tr><td>Cl2</td><td>O2</td><td>HBr</td></tr>
<tr><td>1(5秒)</td><td>120</td><td></td><td></td><td>0.1</td><td>160</td><td rowspan="3">500</td><td rowspan="3">5</td></tr>
<tr><td>2</td><td>108</td><td>12</td><td></td><td>0.1</td><td>160</td></tr>
<tr><td>3</td><td></td><td>3</td><td>100</td><td>1</td><td>20</td></tr>
</table>

表1(b)

<table>
<tr><td rowspan="5">プラズマ発光モニタ
切換え</td><td rowspan="2">ステップ</td><td colspan="3">ガス流量(ml/min)</td><td rowspan="2">圧力
(Pa)</td><td rowspan="2">rf電力
(W)</td><td rowspan="2">マイクロ波
(W)</td><td rowspan="2">基板温度
(℃)</td></tr>
<tr><td>Cl2</td><td>O2</td><td>HBr</td></tr>
<tr><td>1(5秒)</td><td>80</td><td></td><td></td><td>0.4</td><td>60</td><td rowspan="3">500</td><td rowspan="3">5</td></tr>
<tr><td>2</td><td>72</td><td>8</td><td></td><td>0.4</td><td>60</td></tr>
<tr><td>3</td><td></td><td>3</td><td>100</td><td>1</td><td>20</td></tr>
</table>

表1(c)

<table>
<tr><td rowspan="5">光干渉式リアルタイム膜厚モニタ
切換え</td><td rowspan="2">ステップ</td><td colspan="3">ガス流量(ml/min)</td><td rowspan="2">圧力
(Pa)</td><td rowspan="2">rf電力
(W)</td><td rowspan="2">マイクロ波
(W)</td><td rowspan="2">基板温度
(℃)</td></tr>
<tr><td>Cl2</td><td>O2</td><td>HBr</td></tr>
<tr><td>1(5秒)</td><td>120</td><td></td><td></td><td>0.1</td><td>160</td><td rowspan="3">500</td><td rowspan="3">5</td></tr>
<tr><td>2</td><td>108</td><td>12</td><td></td><td>0.1</td><td>160</td></tr>
<tr><td>3</td><td></td><td>3</td><td>100</td><td>1</td><td>20</td></tr>
</table>

表1(d)

<table>
<tr><td rowspan="5">光干渉式リアルタイム膜厚モニタ
切換え</td><td rowspan="2">ステップ</td><td colspan="3">ガス流量(ml/min)</td><td rowspan="2">圧力
(Pa)</td><td rowspan="2">rf電力
(W)</td><td rowspan="2">マイクロ波
(W)</td><td rowspan="2">基板温度
(℃)</td></tr>
<tr><td>Cl2</td><td>O2</td><td>HBr</td></tr>
<tr><td>1(5秒)</td><td>80</td><td></td><td></td><td>0.4</td><td>60</td><td rowspan="3">500</td><td rowspan="3">5</td></tr>
<tr><td>2</td><td>72</td><td>8</td><td></td><td>0.4</td><td>60</td></tr>
<tr><td>3</td><td></td><td>3</td><td>100</td><td>1</td><td>20</td></tr>
</table>

【0025】

【表2】

表2(a)

プラズマ発光モニタ，0.13Pa

	孤立パターン		密部	
	CDシフト（μm）	マイクロトレンチ	CDシフト（μm）	マイクロトレンチ
ウエハ中央	+0.002	あり	-0.001	なし
ウエハ周辺	+0.001	あり	-0.003	あり

表2(b)

プラズマ発光モニタ，0.4Pa

	孤立パターン		密部	
	CDシフト（μm）	マイクロトレンチ	CDシフト（μm）	マイクロトレンチ
ウエハ中央	+0.021	あり	-0.006	あり
ウエハ周辺	+0.016	あり	-0.008	あり

表2(c)

光干渉式リアルタイム膜厚モニタ，0.13Pa

	孤立パターン		密部	
	CDシフト（μm）	マイクロトレンチ	CDシフト（μm）	マイクロトレンチ
ウエハ中央	+0.002	なし	0.000	なし
ウエハ周辺	+0.001	なし	-0.001	なし

表2(d)

光干渉式リアルタイム膜厚モニタ，0.4Pa

	孤立パターン		密部	
	CDシフト（μm）	マイクロトレンチ	CDシフト（μm）	マイクロトレンチ
ウエハ中央	+0.012	なし	-0.002	なし
ウエハ周辺	+0.010	あり	-0.003	あり

【００２６】プラズマ発光モニタを使用した場合、発光強度(波長391nm)の時間二次差分が零になったところでオーバーエッチング条件(ステップ3)に切り換えた。プラズマ発光モニタは、ポリシリコン膜303のエッチングが終了しプラズマ中のシリコン濃度が十分低下した時刻を検知するため、ここで条件を切替えてもゲート酸化膜302の一部分はすでにプラズマに晒されている(図4a,図4b)。ガス圧力0.1Paのエッチングでは選択比が不足して基板301にマイクロトレンチが発生した(表2a)。一方、ガス圧力0.4Paの場合はマイクロトレンチが発生したことに加えて、ウエハ内の最大寸法差(=[ウエハ中央部孤立パターン幅] - [ウエハ周辺部密パターン幅])が0.029μmもあり，面内形状差や疎密形状差は目標値を越えている(表2b)。

【００２７】次に，光干渉式リアルタイム膜厚モニタ使用時のエッチング結果について述べる。本実施例では波長300nmの光をモニタした。波長が短いほど膜厚分解能が上がる。ただし、ポリシリコンの屈折率が安定な波長域は290-360nmであるため、この範囲の波長を選択することが望ましい。ここでは310nmの光でモニタした。ポリシリコンの屈折率が5.2であるため、ポリシリコン中の波長は60nmである。したがって、残膜厚30nmが十分検知できる精度を有している。ガス圧力0.1Paでエッチングする場合でも、塩素(Cl_2)/酸素(O_2)総ガス流量を120ml/minに増やし、rf電力を160Wに高めたことで、実用速度300nm/minが得られた。ポリシリコン残膜厚が30nmまで減少した時点でオーバーエッチング条件(臭化水素(HBr)/O_2、ガス圧力1Pa、rf電力 20W)に切替えたため(図4c)、酸化膜厚が3nmであるにもかかわらずマイクロトレンチは発生しなかった(表2c)。ポリシリコン膜303が消失する前にrf電力を下げたのでチャージアップダメージも発生しなかった。そのため、ウエハ内の最大寸法差を0.003μmまで抑制することができた(表2c)。

【００２８】これに対し、ガス圧力0.4Paでステップ2のエッチングを行った場合の最大寸法差は、0.015μmと大きかった。マイクロローディングによるエッチング速度差は9%に達し(図4d)、光干渉式リアルタイム膜厚モニタによる残膜厚の測定が不正確になりウエハ周辺部でマイクロトレンチが発生した(表2d)。

【００２９】以上の検討から、ガス圧力0.1Paでエッチングし光干渉式リアルタイム膜厚モニタを用いてエッチング条件を切り換える方法が最も優れていることが理解できる。

【００３０】(実施例2)図5にエッチング試料の断面構造

を示す。直径300mmのシリコンウエハ501上に3nmの酸化膜502、70nmのn$^+$ドープドポリシリコン膜503、5nmの窒化タングステン膜504、150nmのタングステン膜505、200nmの窒化シリコン膜506がこの順に積層されている。窒化シリコン膜506はレジストマスクによって加工されており、最小線幅は0.18μmである。

【0031】0.4Paでエッチングした場合、ラジカル反応がまだ活発であるためタングステン膜505のエッチングが均一に進行しないこと、タングステン膜505のエッチングが高速になる条件ではポリシリコン膜503のエッチングも高速になり酸化膜502との選択比確保が困難になることが問題になった。これらの問題は次のように解決した。

【0032】上層のタングステン膜505を反応ガスCl_2(30ml/min)/O_2(10ml/min)を用いてガス圧力0.08Pa、rf電力160Wでエッチングした。この場合もポリシリコン/タングステンの選択比はやはり確保できないが、タングステン膜505のエッチングが均一に進行するという長所がある。光干渉式リアルタイム膜厚モニタではタングステン膜505の膜厚変化は分からないが、窒化タングステン膜504のエッチング終点ではウエハの反射率が大きく変化するため、終点検出は十分可能である。そこで、この信号をトリガとしてrf電力を100Wまで下げ、ポリシリコン膜503をエッチングし、残膜厚20nmになった時点で反応ガスをHBr(150ml/min)/O_2(3ml/min)に切り換え、さらに圧力を1.2Paまで上げrf電力を30Wまで下げてこれまでのエッチング時間に対し50%のオーバーエッチングを行った。ポリシリコン膜503のエッチングが始まったところでrf電力を下げたため、ポリシリコン膜503のエッチング速度が低下した。ポリシリコン膜503の初期膜厚が70nmと薄い場合でも残膜厚20nmでの切替えが可能になった。また、オーバーエッチング時に選択性の高いHBr/O_2ガスを用いたことによりマイクロトレンチの発生を防止することができた。CDは0.18±0.006μmであり、高精度加工を実現した。この例に示されるように、低ガス圧力エッチングと組み合わせることで、光干渉式リアルタイム膜厚モニタの能力を十分引き出すことができた。

【0033】(実施例3)図5の試料において上層のタングステン膜505をCl_2(30ml/min)/O_2(10ml/min)を用いてガス圧力0.08Pa、rf電力160Wでエッチングした。光干渉式リアルタイム膜厚モニタで観測し、ウエハの反射率が大きく変化した時点で反応ガスをCl_2(72ml/min)/O_2(8ml/min)に切り換え圧力を0.4Paまで上げrf電力を60Wまで下げ、かつ図6に示すようにrf電力をON-OFF変調してポリ

シリコンをエッチングした。ON-OFFの周期1kHz，ON時間のデューティ比は30%とした。さらに，ポリシリコンの残膜厚が20nmになった時点でON-OFF周期1kHz、ON時間のデューティ比15%でrf電力のON-OFF変調を行ないこれまでのエッチング時間に対し100%のオーバーエッチングを加えた。ON-OFF変調を行うことでポリシリコン/酸化膜の選択比が高くなり、マイクロトレンチの発生を防止することができた。さらに、検討を加え、このON-OFF変調でduty比を20%以下にすればポリシリコン/酸化膜の選択比が100を越え、マイクロトレンチ防止に効果的であることを明らかにした。

【0034】

【発明の効果】以上の説明から明らかなように、本発明によれば、MOSトランジスタのゲート加工に光干渉式リアルタイム膜厚モニタを使用することで、0.1Pa以下の低圧エッチングを実施した場合の弊害を除き、加工精度を大幅に改善することができる。すなわち，ポリシリコンのエッチング終点付近で発生する酸化膜のマイクロトレンチやチャージアップダメージを防ぎ、低圧エッチングの効果として直径300mmのウエハでも面内形状差や疎密形状差を0.01μm以下に低減することができる。

【図面の簡単な説明】

【図1】本発明を適用したのエッチング装置を示す図である。

【図2】光干渉式リアル膜厚モニタで得られた反射光強度の時間変化を示す図である。

【図3】実施例で用いた試料の断面構造を示す図である。

【図4】エッチング時のモニタ信号と膜厚の時間変化を示す図である。

【図5】実施例で用いた試料の断面構造を示す図である。

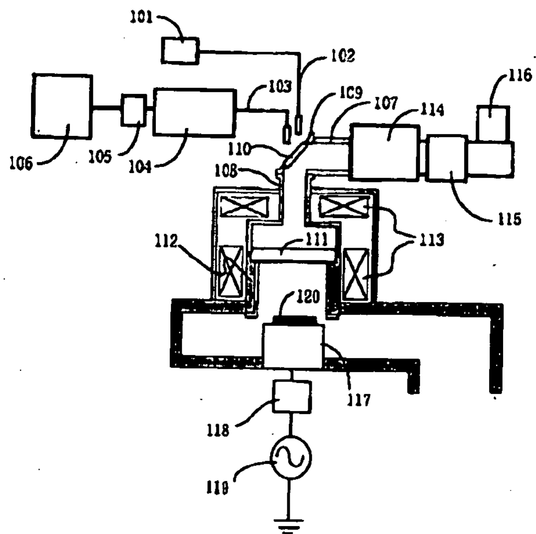
【図6】rf電力のon-off変調の説明図である。

【符号の説明】

101…白色光光源、102,103…光ファイバー、104…分光器もしくは光フィルター、105…光電増倍管、106…波形解析装置、107…矩形導波管、108…円形導波管、109…変換導波管、110,111…石英窓、112…反応容器、113…ソレノイド、114…チューナー、115…アイソレータ、116…マグネトロン、117…電極、118…マッチングボックス，119…rf電源，120…ウエハ，301,501…シリコン基板，302,502…ゲート酸化膜、303,503…ポリシリコン膜、304,506…窒化シリコン膜、504…窒化タングステン膜、505…タングステン膜。

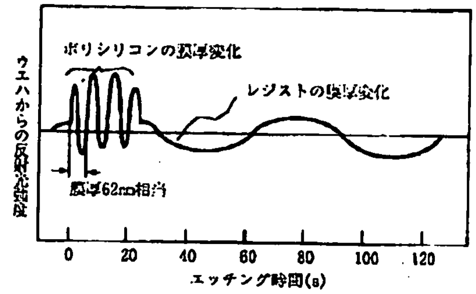
【図1】

図1



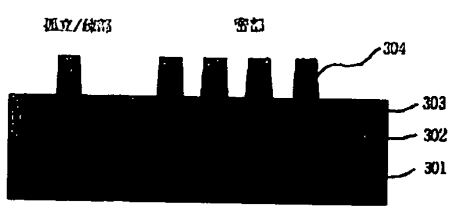
【図2】

図2



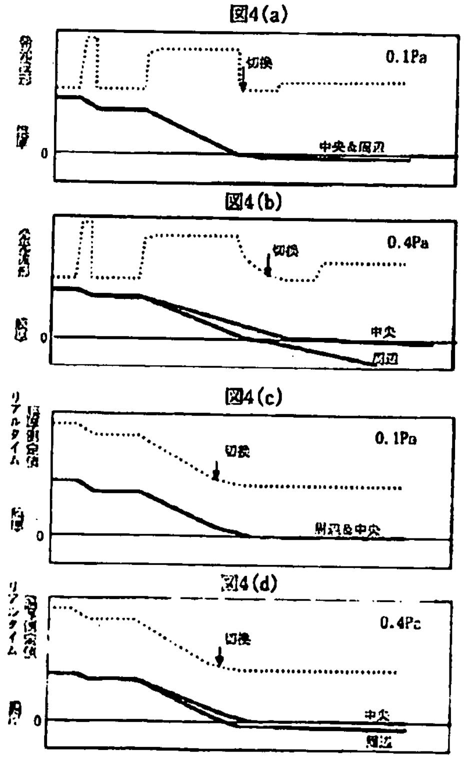
【図3】

図3



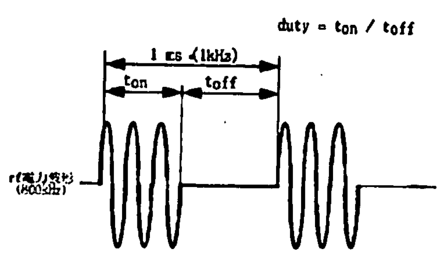
【図4】

図4(a)



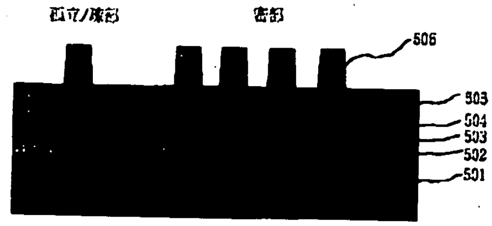
【図6】

図6



【図5】

図5



JP11-260799

CLAIMS

[Claim(s)]
[Claim 1] The micro-processing approach of the thin film characterized by detecting that the transparence thin films of said sample decreased in number to predetermined thickness by the real-time thickness monitor in the process which etches the sample which has a transparent thin film optically using the plasma with a pressure of 0.1Pa or less, answering the detection concerned, and changing etching conditions.
[Claim 2] The micro-processing approach of the thin film according to claim 1 characterized by raising gas pressure to 1Pa or more after the predetermined thickness detection by the real-time thickness monitor.
[Claim 3] The micro-processing approach of the thin film according to claim 1 characterized by switching reactant gas to the mixed gas of a bromine and oxygen after the predetermined thickness detection by the real-time thickness monitor.
[Claim 4] The micro-processing approach of the thin film according to claim 1 characterized by lowering rf power impressed to a substrate after the predetermined thickness detection by the real-time thickness monitor to less than [30W].
[Claim 5] The micro-processing approach of the thin film according to claim 1 characterized by carrying out the ON-OFF modulation of the rf power impressed to a substrate after the predetermined thickness detection by the real-time thickness monitor at 20% or less of duty ratios.
[Claim 6] The micro-processing approach of a thin film according to claim 1 that etching condition modification after the predetermined thickness detection by the real-time thickness monitor is characterized by combining two or more these, including at least one or more requirements to claims 2-5.
[Claim 7] A real-time thickness monitor is the micro-processing approach of the thin film according to claim 1 which possesses the 1st optical fiber which irradiates the white light of a sample, the 2nd optical fiber which incorporates the reflected light from the sample concerned, the spectroscope which carries out the spectrum of the reflected light incorporated with the 2nd optical fiber concerned, and the photomultiplier tube which changes into an electrical signal the reflected light concerned which carried out the spectrum, and changes.
[Claim 8] A real-time thickness monitor is the micro-processing approach of the thin film according to claim 1 which possesses the 1st optical fiber which irradiates the white light of a sample, the 2nd optical fiber which incorporates the reflected light from the sample concerned, the light filter which filters the reflected light incorporated with the 2nd optical fiber concerned, and the photomultiplier tube which changes the filtered reflected light concerned into an electrical signal, and changes.
[Claim 9] The wavelength of the light used for the etching thickness measurement of polish recon is the micro-processing approach of the thin film characterized by being 290 to 360 nm.

[Translation done.]

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1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the micro-processing approach of a light transmission nature thin film established on the semi-conductor substrate.
[0002]
[Description of the Prior Art] The optical interference type thickness monitor is indicated by 242 pages (Proceedings of Symposium on Dry Process, November 12-14, Tokyo (1997), p.235-242) from 235 pages of the 19th dry-process symposium.
[0003] Moreover, in order to raise the etch uniformity within a wafer side, the method of using a focal ring is indicated by Japanese Patent Application No. 6-033645.
[0004]
[Problem(s) to be Solved by the Invention] From the request of the densification and improvement in the speed of a large-scale integrated circuit (LSI), the gate electrode of an MOS (metal-oxide-semiconductor) transistor is reduced to the line breadth of 0.2 micrometers or less in the future, and the gate oxide of a substrate is thin-film-ized to 4nm or less. A silicon wafer is diameter[of macrostomia]-ized from 200mm to 300mm at coincidence for manufacture cost reduction. Therefore, it is necessary to solve the problem described below in the dry etching of a gate electrode.
[0005] That is, in an MOS transistor, in order to arrange an operating characteristic, it is indispensable to process the dimension (CD;critical dimension) of a gate electrode base in the precision of **0.02 micrometers or less. However, a difference arises in a measurement with the location within a field, or a pattern non-dense consistency. These are called the configuration difference within a field, and an of-condensation-and-rarefaction form letter rack, and have been the failures of micro processing, respectively.
[0006] In a wafer side, when gas concentration and a plasma consistency are uneven, the configuration difference within a field arises. That is, it is in the inclination for a side-attachment-wall deposit to increase and for a pattern to grow fat, in the center section in which the concentration of a resultant becomes high. Moreover, with the diameter wafer of macrostomia, since big concentration distribution arises, the configuration difference within a field becomes more remarkable.
[0007] It is the problem that the of-condensation-and-rarefaction form letter rack produced according to the shielding effect of the pattern itself is also big on the other hand. That is, if pattern spacing becomes narrow, the amount of incidence of ion, or a radical and a resultant will fall. Therefore, a pattern does not grow fat although an etch rate becomes slow. Conversely, by the isolated pattern or the pattern facing an open space, many amounts of incidence of a resultant deposit on a side attachment wall rather than a dense pattern, and it is in the inclination for a pattern to grow fat.
[0008] The above mentioned dimorphism letter rack is strongly influenced of gas pressure. That is, if gas pressure becomes high, in order that collision dispersion of molecules increases, molecule migration to a horizontal direction being controlled and the gas concentration distribution within a field becoming large and collision dispersion may become frequent and the amount of re-incidence of a resultant may

increase, it turns out that the side-attachment-wall alimentation to the non-dense section becomes very large.

[0009] With the conventional etching technique, the ununiformity of gas concentration distribution was offset by adjusting the field internal division cloth of a plasma consistency. However, by this approach, the range of the etching conditions suitable for practical use became narrow, and caused process instability. For this reason, a wafer is surrounded with a ring-like obstruction (focal ring), and the approach of making concentration of a resultant homogeneity is used by stagnating gas in it. However, it is most effective for there to be almost no effective cure means about an of-condensation-and-rarefaction form letter rack, and to lower gas pressure at present.

[0010] Although a form letter rack can be reduced if gas pressure is lowered to 0.1Pa or less, such low voltage force conditions are not liked in the mass production of a semiconductor device. The reason is that there are evils, like that an etch rate falls and a wafer throughput falls, that the selection ratio to gate oxide falls, and the abnormalities in a configuration and charge-up damage by electronic shading occur.

[0011] These problems are also solvable by choosing etching conditions according to an individual. Also with low voltage, bias voltage impressed to a substrate is made high, and polish recon can be etched at **** and the high speed which increase a quantity of gas flow. However, as long as the conventional etching terminal point judging technique is used, etching of low-pressure in near a terminal point and high bias fails. That is, it is because each approach of carrying out the monitor of plasma luminescence or the change of substrate bias voltage is a feedback method, so etching of gate oxide is advancing considerably at the time of terminal point detection. Even if it changes etching conditions at this time, avoid and twist and there is no damage on an oxide film. Therefore, it is indispensable to change into the high etching conditions of a selection ratio, just before gate oxide is exposed.

[0012] The optical interference type thickness monitor (it indicates from 235 pages of the 19th dry-process symposium to 242 pages) was devised, and the thickness measurement of the polish recon under etching recently became possible. However, there is almost no application to etching control.

[0013] The purpose of this invention realizes low gas pressure and high bias voltage, and high quantity-of-gas-flow etching, and is to acquire the micro-processing approach of a thin film that the configuration difference within a field and an of-condensation-and-rarefaction form letter rack can be reduced.

[0014]

[Means for Solving the Problem] In order to attain the above-mentioned purpose, in this invention, it etches to the middle of the polish recon film by the low-gas-pressure force 0.1Pa or less in a gate electrode processing process. Just before it supervises the residual film thickness of polish recon by the optical interference type real-time thickness monitor and gate oxide is exposed during this etching (less than remaining 300nm), it changes to high selective etching conditions.

[0015]

[Embodiment of the Invention] The outline of an etching system which shows one example of this invention in drawing 1 is shown.

[0016] The quartz aperture 110 is formed in the conversion waveguide 109 for introducing microwave into a circular waveguide 108 from rectangle ****** 107, and the optical fiber 103 for incorporating the plasma light reflected on the optical fiber 102 and wafer front face for irradiating the white light at this aperture 110 is installed. 101 is the white light light source and supplies the white light to an optical fiber 102. The spectrum of the incorporated light is carried out with a spectroscope 104, it is changed into an electrical signal using a photomultiplier tube 105, and computes etching thickness with waveform analysis equipment 106. This spectroscope 104 may be a light filter. Like polish recon, optically, with a transparent thin film, since the light reflected on the thin film top face and the light reflected on the thin film inferior surface of tongue interfere, corresponding to the thickness reduction by etching, reflectivity changes periodically. Therefore, when the refractive index of a thin film is known, etching thickness can be calculated from the amount of phase changes. Even when the transparent etching mask of another kind exists on this thin film, measurement of thickness change is possible.

[0017] In addition, as for the magnetron whose 116 is the source of supply of microwave, and 115, in drawing 1, an isolator and 114 are tuners. 112 is a reaction container and it is the solenoid in which 111

forms a quartz aperture in the reaction container 112, and 113 forms a magnetic field. The electrode with which 117 carries a wafer 120, rf power source with which 119 supplies bias power to an electrode 117, and 118 are matching boxes which adjust the power supplied to an electrode 117.
[0018] An example of the light reflex change on the strength at the time of using an organic resist for drawing 2 and performing gate processing of an MOS transistor is shown. This is the result of taking out the reflected light with a wavelength of 320nm with a spectroscope 104, and carrying out the monitor of the change on the strength. According to this, corresponding to the refractive index (n= 5.2) of polish recon being small a figure single [about], the direction of the reflected light from polish recon is changing to the refractive index (n= 1.5) of a resist the period shorter about 3.5 times than the reflected light from an organic resist.
[0019] Even if it uses a silicon nitride film and the silicon oxide film as a processing mask, since it is the same, thickness can be measured on real time. Hereafter, this thickness measurement machine is called an optical interference type real-time thickness monitor.
[0020] In order to perform advanced multi-step etching made into the purpose, it is required to combine low voltage etching and an optical interference type real-time thickness monitor. If it etches with low voltage, the etching speed difference of the inside of a field / roughness and fineness will be lost. Since etching advances to homogeneity in a wafer side, etching thickness can measure correctly by the optical interference type real-time thickness monitor. For this reason, it becomes possible to switch etching conditions with sufficient timing, and low voltage etching can also prevent damage on gate oxide. That is, the capacity of an optical interference type real-time thickness monitor can be enough pulled out by combining with low voltage etching.
[0021] The example of etching by this invention is explained.
[0022] (Example 1) The cross-section structure of an etching sample is shown in drawing 3. As for this, the laminating of the silicon nitride film 304 of 303,200nm of n+ doped polysilicon film of 302,200nm of 3nm oxide films is carried out in this sequence on the silicon wafer 301 with a diameter of 300mm. The silicon nitride film 304 is processed with the resist mask, and minimum line width is 0.13 micrometers.
[0023] Four kinds of multi-step etching approaches are shown in Table 1. Each differs in the gas pressure at the time of etching of the polish recon film 303 (0.1Pa, 0.4Pa), and the combination of the terminal point detection approach (an optical interference type real-time thickness monitor, plasma luminescence monitor). Each etching conditions were beforehand set that rf power and the quantity of gas flow which are impressed to a substrate are adjusted, and the processing time becomes the same. The superiority or inferiority of an all directions method were compared under this premise. Time amount change of each monitor signal and thickness was shown in drawing 4. Moreover, CD shift amount of the isolated pattern in a wafer center section and a periphery and a dense pattern and the generating existence of a micro trench (detailed hole) were shown in Table 2.
[0024]
[Table 1]

表1(a)

プラズマ発光モニタ	ステップ	ガス流量(ml/min)			圧力	rf電力	マイクロ波	基板温度
		Cl2	O2	HBr	(Pa)	(W)	(W)	(℃)
	1(5秒)	120			0.1	160		
	2	108	12		0.1	160	500	5
切換え ▶	3		3	100	1	20		

$\left(\frac{108}{12}\right)^{-1} \rightarrow \left(\frac{100}{3}\right)^{-1}$

0.1 → 0.03 } ΔO2 ratio

表1(b)

プラズマ発光モニタ	ステップ	ガス流量(ml/min)			圧力	rf電力	マイクロ波	基板温度
		Cl2	O2	HBr	(Pa)	(W)	(W)	(℃)
	1(5秒)	80			0.4	60		
	2	72	8		0.4	60	500	5
切換え ▶	3		3	100	1	20		

$\left(\frac{72}{8}\right)^{-1} \rightarrow \left(\frac{100}{3}\right)^{-1}$

0.1 → 0.03

表1(c)

光干渉式リアルタイム膜厚モニタ	ステップ	ガス流量(ml/min)			圧力	rf電力	マイクロ波	基板温度
		Cl2	O2	HBr	(Pa)	(W)	(W)	(℃)
	1(5秒)	120			0.1	160		
	2	108	12		0.1	160	500	5
切換え ▶	3		3	100	1	20		

$\left(\frac{108}{12}\right)^{-1} \rightarrow \left(\frac{100}{3}\right)^{-1}$

表1(d)

光干渉式リアルタイム膜厚モニタ	ステップ	ガス流量(ml/min)			圧力	rf電力	マイクロ波	基板温度
		Cl2	O2	HBr	(Pa)	(W)	(W)	(℃)
	1(5秒)	80			0.4	60		
	2	72	8		0.4	60	500	5
切換え ▶	3		3	100	1	20		

$\left(\frac{72}{8}\right)^{-1} \rightarrow \left(\frac{100}{3}\right)^{-1}$

[0025]
[Table 2]

表2(a)

プラズマ発光モニタ, 0.13Pa

	孤立パターン		密部	
	CDシフト (μm)	マイクロトレンチ	CDシフト (μm)	マイクロトレンチ
ウエハ中央	+0.002	あり	-0.001	なし
ウエハ周辺	+0.001	あり	-0.003	あり

表2(b)

プラズマ発光モニタ, 0.4Pa

	孤立パターン		密部	
	CDシフト (μm)	マイクロトレンチ	CDシフト (μm)	マイクロトレンチ
ウエハ中央	+0.021	あり	-0.006	あり
ウエハ周辺	+0.016	あり	-0.008	あり

表2(c)

光干渉式リアルタイム膜厚モニタ, 0.13Pa

	孤立パターン		密部	
	CDシフト (μm)	マイクロトレンチ	CDシフト (μm)	マイクロトレンチ
ウエハ中央	+0.002	なし	0.000	なし
ウエハ周辺	+0.001	なし	-0.001	なし

表2(d)

光干渉式リアルタイム膜厚モニタ, 0.4Pa

	孤立パターン		密部	
	CDシフト (μm)	マイクロトレンチ	CDシフト (μm)	マイクロトレンチ
ウエハ中央	+0.012	なし	-0.002	なし
ウエハ周辺	+0.010	あり	-0.003	あり

[0026] the case where a plasma luminescence monitor is used -- the time amount secondary of luminescence reinforcement (wavelength of 391nm) -- it switched to over etching conditions (step 3) in the place where difference became zero. In order that a plasma luminescence monitor may detect the time of day when etching of the polish recon film 303 was completed at, and the silicon concentration in the plasma fell enough, even if it changes conditions here, a part of gate oxide 302 is already exposed to the plasma (drawing 4 a, drawing 4 b). By etching with a gas pressure of 0.1Pa, the selection ratio was insufficient and the micro trench was generated in the substrate 301 (table 2a). On the other hand, in the case of 0.4Pa gas pressure, in addition to the micro trench having been generated, there are no less than 0.029 micrometers (=[wafer center-section isolated pattern width of face]- [wafer periphery dense pattern width of face]) of upper limit differences in a wafer, and the configuration difference within a field and the of-condensation-and-rarefaction form letter rack are over desired value (front 2b).
[0027] Next, the etching result at the time of optical interference type real-time thickness monitor use is described. In this example, the monitor of the light with a wavelength of 300nm was carried out. so that wavelength is short -- thickness -- resolution goes up. However, since the wavelength region where the refractive index of polish recon is stable is 290 to 360 nm, it is desirable to choose the wavelength of this range. Here, the monitor was carried out with 310nm light. Since the refractive index of polish recon is 5.2, the wavelength in polish recon is 60nm. Therefore, it has the precision which the residual film thickness of 30nm can detect enough. Even when etching with the gas pressure of 0.1Pa, chlorine (Cl2) / the oxygen (O2) total quantity of gas flow was increased to 120 ml/min, and practical use rate 300 nm/min was obtained by having raised rf power to 160W. Since it changed to over etching conditions (a

hydrogen bromide (HBr) / O2, the gas pressure of 1Pa, rf power 20W) when polish recon residual film thickness decreased to 30nm (drawing 4 c), the micro trench was not generated although oxide film thickness was 3nm (table 2c). Since rf power was lowered before the polish recon layer 303 disappeared, a charge-up damage was not generated, either. Therefore, the upper limit difference in a wafer was able to be controlled to 0.003 micrometers (table 2c).

[0028] On the other hand, the upper limit difference at the time of etching step 2 with the gas pressure of 0.4Pa was as large as 0.015 micrometers. It reached to 9% (drawing 4 d), measurement of the residual film thickness by the optical interference type real-time thickness monitor became incorrectness, and the micro trench generated the etching speed difference by micro loading in the wafer periphery (2d of tables).

[0029] He can understand that the approach of etching with the gas pressure of 0.1Pa and switching etching conditions from the above examination using an optical interference type real-time thickness monitor is most excellent.

[0030] (Example 2) The cross-section structure of an etching sample is shown in drawing 5. The laminating of the silicon nitride film 506 of 505 or 200nm of tungsten film of 504 or 150nm of nitriding tungsten film of 503 or 5nm of n+ doped polysilicon film of 502 or 70nm of 3nm oxide films is carried out to this order on the silicon wafer 501 with a diameter of 300mm. The silicon nitride film 506 is processed with the resist mask, and minimum line width is 0.18 micrometers.

[0031] When it etched by 0.4Pa, since radical reaction was still active, it became a problem that etching of the tungsten film 505 does not advance to homogeneity and that etching of the polish recon film 503 also becomes a high speed on the conditions from which etching of the tungsten film 505 becomes a high speed, and selection-ratio reservation with an oxide film 502 becomes difficult. These problems were solved as follows.

[0032] The upper tungsten film 505 was etched by the gas pressure of 0.08Pa, and rf power 160W using reactant gas Cl2 (30 ml/min)/O2 (10 ml/min). Although the selection ratio of polish recon / tungsten is not securable too in this case, there is the advantage in which etching of the tungsten film 505 advances to homogeneity. Although thickness change of the tungsten film 505 is not known in an optical interference type real-time thickness monitor, since the reflection factor of a wafer changes a lot, terminal point detection is possible enough at the etching terminal point of the nitriding tungsten film 504. Then, rf power was lowered to 100W by making this signal into a trigger, the polish recon film 503 was etched, when it became the residual film thickness of 20nm, reactant gas was switched to HBr (150 ml/min)/O2 (3 ml/min), the pressure was further raised to 1.2Pa, rf power was lowered to 30W, and 50% of over etching was performed to the etching time of until. Since rf power was lowered in the place where etching of the polish recon film 503 started, the etch rate of the polish recon film 503 fell. Even when the initial thickness of the polish recon film 503 was as thin as 70nm, the change with the residual film thickness of 20nm was attained. Moreover, generating of a micro trench was able to be prevented by having used HBr/O2 high gas of selectivity at the time of over etching. CD is 0.18**0.006 micrometers and realized high precision processing. As shown in this example, the capacity of an optical interference type real-time thickness monitor was able to be enough pulled out by combining with low-gas-pressure force etching.

[0033] (Example 3) In the sample of drawing 5, the upper tungsten film 505 was etched by the gas pressure of 0.08Pa, and rf power 160W using Cl2 (30 ml/min)/O2 (10 ml/min). As it observes by the optical interference type real-time thickness monitor, switch reactant gas to Cl2 (72 ml/min)/O2 (8 ml/min), a pressure was raised to 0.4Pa, and rf power was lowered to 60W, when the reflection factor of a wafer changes a lot, and shown in drawing 6, the ON-OFF modulation of the rf power was carried out, and polish recon was etched. The period of 1kHz of ON-OFF and the duty ratio of ON time amount were made into 30%. Furthermore, when the residual film thickness of polish recon was set to 20nm, the ON-OFF modulation of rf power was performed at 15% of duty ratios of the ON-OFF period of 1kHz, and ON time amount, and 100% of over etching was added to old etching time. The selection ratio of polish recon / oxide film was able to become high by performing an ON-OFF modulation, and generating of a micro trench was able to be prevented. Furthermore, when adding examination and

making the duty ratio 20% or less in this ON-OFF modulation, the selection ratio of polish recon / oxide film exceeded 100, and showed clearly that it is effective for micro trench prevention.

[0034]

[Effect of the Invention] According to this invention, except for the evil at the time of carrying out low voltage etching of 0.1Pa or less, process tolerance is sharply improvable by using an optical interference type real-time thickness monitor for gate processing of an MOS transistor so that clearly from the above explanation. That is, the micro trench and charge-up damage of the oxide film generated near the etching terminal point of polish recon can be prevented, and a wafer with a diameter of 300mm can also reduce the form letter rack within a field, and an of-condensation-and-rarefaction form letter rack to 0.01 micrometers or less as effectiveness of low voltage etching.

[Translation done.]

* NOTICES *

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1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

TECHNICAL FIELD

[Field of the Invention] This invention relates to the micro-processing approach of a light transmission nature thin film established on the semi-conductor substrate.

[Translation done.]

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PRIOR ART

[Description of the Prior Art] The optical interference type thickness monitor is indicated by 242 pages (Proceedings of Symposium on Dry Process, November 12-14, Tokyo (1997), p.235-242) from 235 pages of the 19th dry-process symposium.
[0003] Moreover, in order to raise the etch uniformity within a wafer side, the method of using a focal ring is indicated by Japanese Patent Application No. 6-033645.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] According to this invention, except for the evil at the time of carrying out low voltage etching of 0.1Pa or less, process tolerance is sharply improvable by using an optical interference type real-time thickness monitor for gate processing of an MOS transistor so that clearly from the above explanation. That is, the micro trench and charge-up damage of the oxide film generated near the etching terminal point of polish recon can be prevented, and a wafer with a diameter of 300mm can also reduce the form letter rack within a field, and an of-condensation-and-rarefaction form letter rack to 0.01 micrometers or less as effectiveness of low voltage etching.

[Translation done.]

* NOTICES *

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] From the request of the densification and improvement in the speed of a large-scale integrated circuit (LSI), the gate electrode of an MOS (metal-oxide-semiconductor) transistor is reduced to the line breadth of 0.2 micrometers or less in the future, and the gate oxide of a substrate is thin-film-ized to 4nm or less. A silicon wafer is diameter[of macrostomia]-ized from 200mm to 300mm at coincidence for manufacture cost reduction. Therefore, it is necessary to solve the problem described below in the dry etching of a gate electrode.
[0005] That is, in an MOS transistor, in order to arrange an operating characteristic, it is indispensable to process the dimension (CD;critical dimension) of a gate electrode base in the precision of **0.02 micrometers or less. However, a difference arises in a measurement with the location within a field, or a pattern non-dense consistency. These are called the configuration difference within a field, and an of-condensation-and-rarefaction form letter rack, and have been the failures of micro processing, respectively.
[0006] In a wafer side, when gas concentration and a plasma consistency are uneven, the configuration difference within a field arises. That is, it is in the inclination for a side-attachment-wall deposit to increase and for a pattern to grow fat, in the center section in which the concentration of a resultant becomes high. Moreover, with the diameter wafer of macrostomia, since big concentration distribution arises, the configuration difference within a field becomes more remarkable.
[0007] It is the problem that the of-condensation-and-rarefaction form letter rack produced according to the shielding effect of the pattern itself is also big on the other hand. That is, if pattern spacing becomes narrow, the amount of incidence of ion, or a radical and a resultant will fall. Therefore, a pattern does not grow fat although an etch rate becomes slow. Conversely, by the isolated pattern or the pattern facing an open space, many amounts of incidence of a resultant deposit on a side attachment wall rather than a dense pattern, and it is in the inclination for a pattern to grow fat.
[0008] The above mentioned dimorphism letter rack is strongly influenced of gas pressure. That is, if gas pressure becomes high, in order that collision dispersion of molecules increases, molecule migration to a horizontal direction being controlled and the gas concentration distribution within a field becoming large and collision dispersion may become frequent and the amount of re-incidence of a resultant may increase, it turns out that the side-attachment-wall alimentation to the non-dense section becomes very large.
[0009] With the conventional etching technique, the ununiformity of gas concentration distribution was offset by adjusting the field internal division cloth of a plasma consistency. However, by this approach, the range of the etching conditions suitable for practical use became narrow, and caused process instability. For this reason, a wafer is surrounded with a ring-like obstruction (focal ring), and the approach of making concentration of a resultant homogeneity is used by stagnating gas in it. However, it is most effective for there to be almost no effective cure means about an of-condensation-and-rarefaction form letter rack, and to lower gas pressure at present.
[0010] Although a form letter rack can be reduced if gas pressure is lowered to 0.1Pa or less, such low voltage force conditions are not liked in the mass production of a semiconductor device. The reason is

that there are evils, like that an etch rate falls and a wafer throughput falls, that the selection ratio to gate oxide falls, and the abnormalities in a configuration and charge-up damage by electronic shading occur.
[0011] These problems are also solvable by choosing etching conditions according to an individual. Also with low voltage, bias voltage impressed to a substrate is made high, and polish recon can be etched at **** and the high speed which increase a quantity of gas flow. However, as long as the conventional etching terminal point judging technique is used, etching of low-pressure in near a terminal point and high bias fails. That is, it is because each approach of carrying out the monitor of plasma luminescence or the change of substrate bias voltage is a feedback method, so etching of gate oxide is advancing considerably at the time of terminal point detection. Even if it changes etching conditions at this time, avoid and twist and there is no damage on an oxide film. Therefore, it is indispensable to change into the high etching conditions of a selection ratio, just before gate oxide is exposed.
[0012] The optical interference type thickness monitor (it indicates from 235 pages of the 19th dry-process symposium to 242 pages) was devised, and the thickness measurement of the polish recon under etching recently became possible. However, there is almost no application to etching control.
[0013] The purpose of this invention realizes low gas pressure and high bias voltage, and high quantity-of-gas-flow etching, and is to acquire the micro-processing approach of a thin film that the configuration difference within a field and an of-condensation-and-rarefaction form letter rack can be reduced.

[Translation done.]

MEANS

[Means for Solving the Problem] In order to attain the above-mentioned purpose, in this invention, it etches to the middle of the polish recon film by the low-gas-pressure force 0.1Pa or less in a gate electrode processing process. Just before it supervises the residual film thickness of polish recon by the optical interference type real-time thickness monitor and gate oxide is exposed during this etching (less than remaining 300nm), it changes to high selective etching conditions.
[0015]
[Embodiment of the Invention] The outline of an etching system which shows one example of this invention in drawing 1 is shown.
[0016] The quartz aperture 110 is formed in the conversion waveguide 109 for introducing microwave into a circular waveguide 108 from rectangle ****** 107, and the optical fiber 103 for incorporating the plasma light reflected on the optical fiber 102 and wafer front face for irradiating the white light at this aperture 110 is installed. 101 is the white light light source and supplies the white light to an optical fiber 102. The spectrum of the incorporated light is carried out with a spectroscope 104, it is changed into an electrical signal using a photomultiplier tube 105, and computes etching thickness with waveform analysis equipment 106. This spectroscope 104 may be a light filter. Like polish recon, optically, with a transparent thin film, since the light reflected on the thin film top face and the light reflected on the thin film inferior surface of tongue interfere, corresponding to the thickness reduction by etching, reflectivity changes periodically. Therefore, when the refractive index of a thin film is known, etching thickness can be calculated from the amount of phase changes. Even when the transparent etching mask of another kind exists on this thin film, measurement of thickness change is possible.
[0017] In addition, as for the magnetron whose 116 is the source of supply of microwave, and 115, in drawing 1, an isolator and 114 are tuners. 112 is a reaction container and it is the solenoid in which 111 forms a quartz aperture in the reaction container 112, and 113 forms a magnetic field. The electrode with which 117 carries a wafer 120, rf power source with which 119 supplies bias power to an electrode 117, and 118 are matching boxes which adjust the power supplied to an electrode 117.
[0018] An example of the light reflex change on the strength at the time of using an organic resist for drawing 2 and performing gate processing of an MOS transistor is shown. This is the result of taking out the reflected light with a wavelength of 320nm with a spectroscope 104, and carrying out the monitor of the change on the strength. According to this, corresponding to the refractive index (n= 5.2) of polish recon being small a figure single [about], the direction of the reflected light from polish recon is changing to the refractive index (n= 1.5) of a resist the period shorter about 3.5 times than the reflected light from an organic resist.
[0019] Even if it uses a silicon nitride film and the silicon oxide film as a processing mask, since it is the same, thickness can be measured on real time. Hereafter, this thickness measurement machine is called an optical interference type real-time thickness monitor.
[0020] In order to perform advanced multi-step etching made into the purpose, it is required to combine low voltage etching and an optical interference type real-time thickness monitor. If it etches with low voltage, the etching speed difference of the inside of a field / roughness and fineness will be lost. Since

etching advances to homogeneity in a wafer side, etching thickness can measure correctly by the optical interference type real-time thickness monitor. For this reason, it becomes possible to switch etching conditions with sufficient timing, and low voltage etching can also prevent damage on gate oxide. That is, the capacity of an optical interference type real-time thickness monitor can be enough pulled out by combining with low voltage etching.

[0021] The example of etching by this invention is explained.

[0022] (Example 1) The cross-section structure of an etching sample is shown in drawing 3. As for this, the laminating of the silicon nitride film 304 of 303,200nm of n+ doped polysilicon film of 302,200nm of 3nm oxide films is carried out in this sequence on the silicon wafer 301 with a diameter of 300mm. The silicon nitride film 304 is processed with the resist mask, and minimum line width is 0.13 micrometers.

[0023] Four kinds of multi-step etching approaches are shown in Table 1. Each differs in the gas pressure at the time of etching of the polish recon film 303 (0.1Pa, 0.4Pa), and the combination of the terminal point detection approach (an optical interference type real-time thickness monitor, plasma luminescence monitor). Each etching conditions were beforehand set that rf power and the quantity of gas flow which are impressed to a substrate are adjusted, and the processing time becomes the same. The superiority or inferiority of an all directions method were compared under this premise. Time amount change of each monitor signal and thickness was shown in drawing 4. Moreover, CD shift amount of the isolated pattern in a wafer center section and a periphery and a dense pattern and the generating existence of a micro trench (detailed hole) were shown in Table 2.

[0024]

[Table 1]

表1(a)

<table>
<tr><td rowspan="5">プラズマ発光モニタ
切換え</td><td rowspan="2">ステップ</td><td colspan="3">ガス流量(ml/min)</td><td>圧力</td><td>rf電力</td><td>マイクロ波</td><td>基板温度</td></tr>
<tr><td>Cl2</td><td>O2</td><td>HBr</td><td>(Pa)</td><td>(W)</td><td>(W)</td><td>(℃)</td></tr>
<tr><td>1(5秒)</td><td>120</td><td></td><td></td><td>0.1</td><td>160</td><td rowspan="3">500</td><td rowspan="3">5</td></tr>
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</table>

表1(b)

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</table>

表1(c)

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[0025]
[Table 2]

表2(a)

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	CDシフト（μm）	マイクロトレンチ	CDシフト（μm）	マイクロトレンチ
ウエハ中央	+0.002	なし	0.000	なし
ウエハ周辺	+0.001	なし	-0.001	なし

表2(d)

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	CDシフト（μm）	マイクロトレンチ	CDシフト（μm）	マイクロトレンチ
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[0026] the case where a plasma luminescence monitor is used -- the time amount secondary of luminescence reinforcement (wavelength of 391nm) -- it switched to over etching conditions (step 3) in the place where difference became zero. In order that a plasma luminescence monitor may detect the time of day when etching of the polish recon film 303 was completed at, and the silicon concentration in the plasma fell enough, even if it changes conditions here, a part of gate oxide 302 is already exposed to the plasma (drawing 4 a, drawing 4 b). By etching with a gas pressure of 0.1Pa, the selection ratio was insufficient and the micro trench was generated in the substrate 301 (table 2a). On the other hand, in the case of 0.4Pa gas pressure, in addition to the micro trench having been generated, there are no less than 0.029 micrometers (=[wafer center-section isolated pattern width of face]- [wafer periphery dense pattern width of face]) of upper limit differences in a wafer, and the configuration difference within a field and the of-condensation-and-rarefaction form letter rack are over desired value (front 2b).
[0027] Next, the etching result at the time of optical interference type real-time thickness monitor use is described. In this example, the monitor of the light with a wavelength of 300nm was carried out. so that wavelength is short -- thickness -- resolution goes up. However, since the wavelength region where the refractive index of polish recon is stable is 290 to 360 nm, it is desirable to choose the wavelength of this range. Here, the monitor was carried out with 310nm light. Since the refractive index of polish recon is 5.2, the wavelength in polish recon is 60nm. Therefore, it has the precision which the residual film thickness of 30nm can detect enough. Even when etching with the gas pressure of 0.1Pa, chlorine (Cl_2) / the oxygen (O_2) total quantity of gas flow was increased to 120 ml/min, and practical use rate 300 nm/min was obtained by having raised rf power to 160W. Since it changed to over etching conditions (a

hydrogen bromide (HBr) / O2, the gas pressure of 1Pa, rf power 20W) when polish recon residual film thickness decreased to 30nm (drawing 4 c), the micro trench was not generated although oxide film thickness was 3nm (table 2c). Since rf power was lowered before the polish recon layer 303 disappeared, a charge-up damage was not generated, either. Therefore, the upper limit difference in a wafer was able to be controlled to 0.003 micrometers (table 2c).

[0028] On the other hand, the upper limit difference at the time of etching step 2 with the gas pressure of 0.4Pa was as large as 0.015 micrometers. It reached to 9% (drawing 4 d), measurement of the residual film thickness by the optical interference type real-time thickness monitor became incorrectness, and the micro trench generated the etching speed difference by micro loading in the wafer periphery (2d of tables).

[0029] He can understand that the approach of etching with the gas pressure of 0.1Pa and switching etching conditions from the above examination using an optical interference type real-time thickness monitor is most excellent.

[0030] (Example 2) The cross-section structure of an etching sample is shown in drawing 5. The laminating of the silicon nitride film 506 of 505 or 200nm of tungsten film of 504 or 150nm of nitriding tungsten film of 503 or 5nm of n+ doped polysilicon film of 502 or 70nm of 3nm oxide films is carried out to this order on the silicon wafer 501 with a diameter of 300mm. The silicon nitride film 506 is processed with the resist mask, and minimum line width is 0.18 micrometers.

[0031] When it etched by 0.4Pa, since radical reaction was still active, it became a problem that etching of the tungsten film 505 does not advance to homogeneity and that etching of the polish recon film 503 also becomes a high speed on the conditions from which etching of the tungsten film 505 becomes a high speed, and selection-ratio reservation with an oxide film 502 becomes difficult. These problems were solved as follows.

[0032] The upper tungsten film 505 was etched by the gas pressure of 0.08Pa, and rf power 160W using reactant gas Cl2 (30 ml/min)/O2 (10 ml/min). Although the selection ratio of polish recon / tungsten is not securable too in this case, there is the advantage in which etching of the tungsten film 505 advances to homogeneity. Although thickness change of the tungsten film 505 is not known in an optical interference type real-time thickness monitor, since the reflection factor of a wafer changes a lot, terminal point detection is possible enough at the etching terminal point of the nitriding tungsten film 504. Then, rf power was lowered to 100W by making this signal into a trigger, the polish recon film 503 was etched, when it became the residual film thickness of 20nm, reactant gas was switched to HBr (150 ml/min)/O2 (3 ml/min), the pressure was further raised to 1.2Pa, rf power was lowered to 30W, and 50% of over etching was performed to the etching time of until. Since rf power was lowered in the place where etching of the polish recon film 503 started, the etch rate of the polish recon film 503 fell. Even when the initial thickness of the polish recon film 503 was as thin as 70nm, the change with the residual film thickness of 20nm was attained. Moreover, generating of a micro trench was able to be prevented by having used HBr/O2 high gas of selectivity at the time of over etching. CD is 0.18**0.006 micrometers and realized high precision processing. As shown in this example, the capacity of an optical interference type real-time thickness monitor was able to be enough pulled out by combining with low-gas-pressure force etching.

[0033] (Example 3) In the sample of drawing 5, the upper tungsten film 505 was etched by the gas pressure of 0.08Pa, and rf power 160W using Cl2 (30 ml/min)/O2 (10 ml/min). As it observes by the optical interference type real-time thickness monitor, switch reactant gas to Cl2 (72 ml/min)/O2 (8 ml/min), a pressure was raised to 0.4Pa, and rf power was lowered to 60W, when the reflection factor of a wafer changes a lot, and shown in drawing 6, the ON-OFF modulation of the rf power was carried out, and polish recon was etched. The period of 1kHz of ON-OFF and the duty ratio of ON time amount were made into 30%. Furthermore, when the residual film thickness of polish recon was set to 20nm, the ON-OFF modulation of rf power was performed at 15% of duty ratios of the ON-OFF period of 1kHz, and ON time amount, and 100% of over etching was added to old etching time. The selection ratio of polish recon / oxide film was able to become high by performing an ON-OFF modulation, and generating of a micro trench was able to be prevented. Furthermore, when adding examination and

making the duty ratio 20% or less in this ON-OFF modulation, the selection ratio of polish recon / oxide film exceeded 100, and showed clearly that it is effective for micro trench prevention.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is drawing showing an applying-this invention etching system.
[Drawing 2] It is drawing showing time amount change of the reflected light reinforcement obtained by the optical interference type real thickness monitor.
[Drawing 3] It is drawing showing the cross-section structure of the sample used in the example.
[Drawing 4] It is drawing showing time amount change of the monitor signal at the time of etching; and thickness.
[Drawing 5] It is drawing showing the cross-section structure of the sample used in the example.
[Drawing 6] It is the explanatory view of the on-off modulation of rf power.
[Description of Notations]
101 -- The white light light source, 102,103 -- An optical fiber, 104 -- A spectroscope or a light filter, 105 -- A photomultiplier tube, 106 -- Waveform analysis equipment, 107 -- Rectangular waveguide, 108 -- A circular waveguide, 109 -- A conversion waveguide, 110,111 -- Quartz aperture, 112 [-- Isolator,] -- A reaction container, 113 -- A solenoid, 114 -- A tuner, 115 116 [-- rf power source, 120 / -- A wafer, 301,501 / -- A silicon substrate, 302,502 / -- Gate oxide,] -- A magnetron, 117 -- An electrode, 118 -- A matching box, 119 303,503 [-- Tungsten film.] -- The polish recon film, 304,506 -- A silicon nitride film, 504 -- The nitriding tungsten film, 505

[Translation done.]

* NOTICES *

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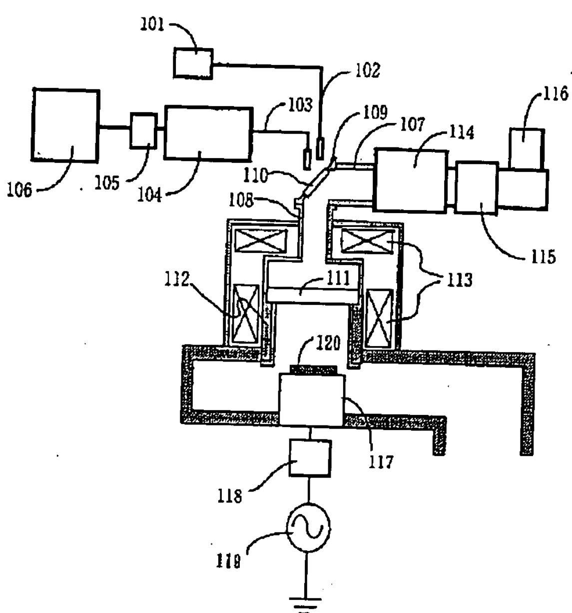
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

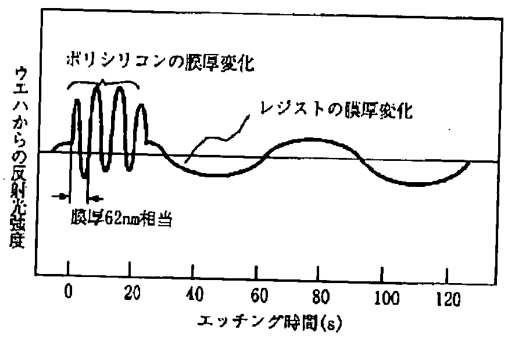
[Drawing 1]

図1



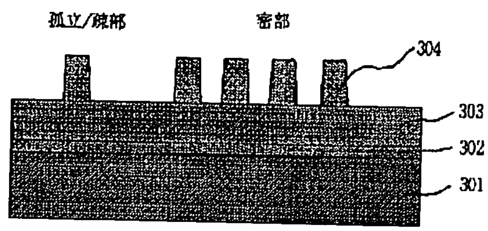
[Drawing 2]

図2



[Drawing 3]

図3



[Drawing 4]

図4(a)

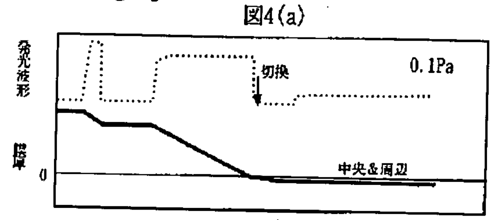


図4(b)

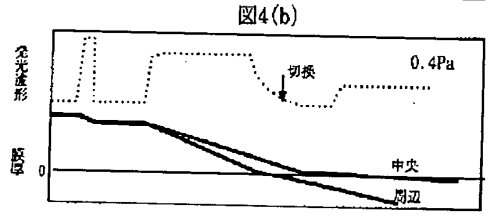


図4(c)

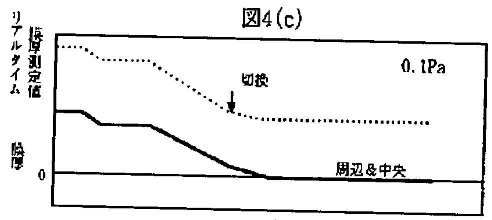
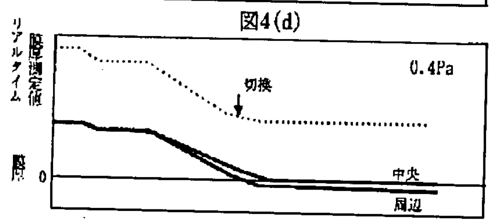
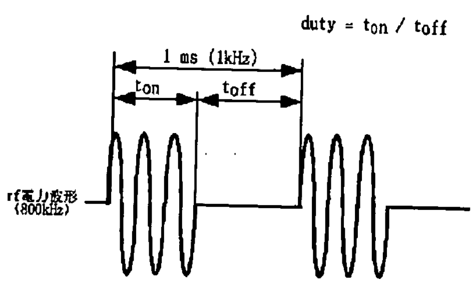


図4(d)



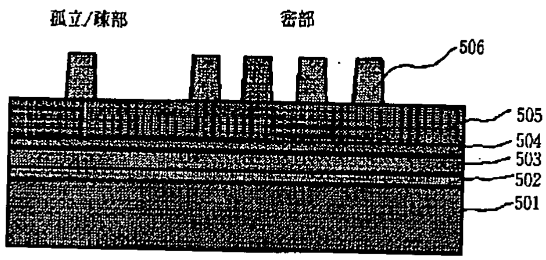
[Drawing 6]

図6



[Drawing 5]

図5



[Translation done.]